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## **Thermodynamic Optimism: Three Energy / Material Dialogues**

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### **ABSTRACT**

The built environment is increasingly understood as part of a thermodynamic regime, yet the fundamental physical processes that govern that regime are not broadly understood within the discipline. This paper explores spatial implications of the laws of thermodynamics in order to expand architecture's energetic epistemology. It then elaborates on a single topic of central concern to developing a more generous and expanded reading of energy in architecture, the relationship between matter and energy. Drawing from student work completed in a University of Edinburgh third year design studio, "Drawing Energy Kerrera," three energy/material dialogues are explored: fluid fronts, material registration, and material geographies. These readings offer a softer, more qualitative framework for engaging with energy generatively and introduce a methodological counterpoint or supplement to conventional metric-based analytic approaches for analysing energy in sustainable design.

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## THERMODYNAMIC THINKING

Architectural thermodynamic thinking generally lies in the disciplinary domain of the mechanical engineer or in the sub-disciplinary domain of sustainability metrics. Both focus on a quantitative conservation-based approach, which limits engagement with energy spatially and generatively in the design process. Focusing solely on non-renewable (petroleum-based chemical) energy forecloses broader design possibilities offered by a broader spectrum of energetic conditions and their corresponding spatial “affects” and “effects” (Lally 2009).

The conventional, metric-based approach for analysing energy has limited traction in design thinking because energy is typically evaluated late in the design process and is seen as spatially enigmatic. Despite this, there has been recent interest in developing ways of conceiving of energy in spatially legible terms. Expanded models for thinking about architecture thermodynamically are offered by Hassan Fathy, Phillipe Rahm, Luis Fernandez Galliano, Michelle Addington, Christopher Hight, Sanford Kwinter and others. Their respective approaches offer schematic readings of architecture through a thermodynamic lens, but they are less explicit about how thermodynamic principles might play a generative role in the design process.<sup>1</sup> Engaging more generously with energetic thinking generatively requires a thermodynamic conception of architecture that is qualitatively framed while still being informed by a basic technical understanding of the laws that govern it. A more accurate epistemology of energy in the built environment acknowledges that some energy is of finite stock and its consumption should be reduced, but that other forms of energy are legible, perceivable, in abundance, and of spatial consequence.

A very basic understanding of the laws of thermodynamics yields rich spatial insights. The First Law of Thermodynamics is beautifully tidy; it mirrors the mechanistic thinking that predates its discovery. The Law of Energy Conservation states that energy can neither be created nor destroyed and therefore all energy that will ever exist already exists; it constantly changes form. Because of this constant translation, all forms of energy are ultimately reducible to the same unit of measure. This Law underpins the basic principles of metric-based approaches to sustainability, which rely on unit continuity for comparing, for example, manufacture, transport, installation and demolition energy consumption for calculating embodied energy. This law also offers that energy is in abundance. In “Compelling Yet Unreliable Theories of Sustainability”, Kiel Moe offers an alternate to the “thermodynamically pessimist paradigm,” which focuses on finite resources of non-renewable energy rather than on the enormous magnitude of solar energy that arrives on earth daily. He suggests, “there is in fact no real energy shortage. There is only a crisis of human choices in respect to our energy practices” (2007 p24).

No process is 100% energy-efficient. Because of the energy penalty incurred in establishing equilibrium in a system, processes are not reversible. The Second Law of Energy, The ‘Law of Entropy’, introduces

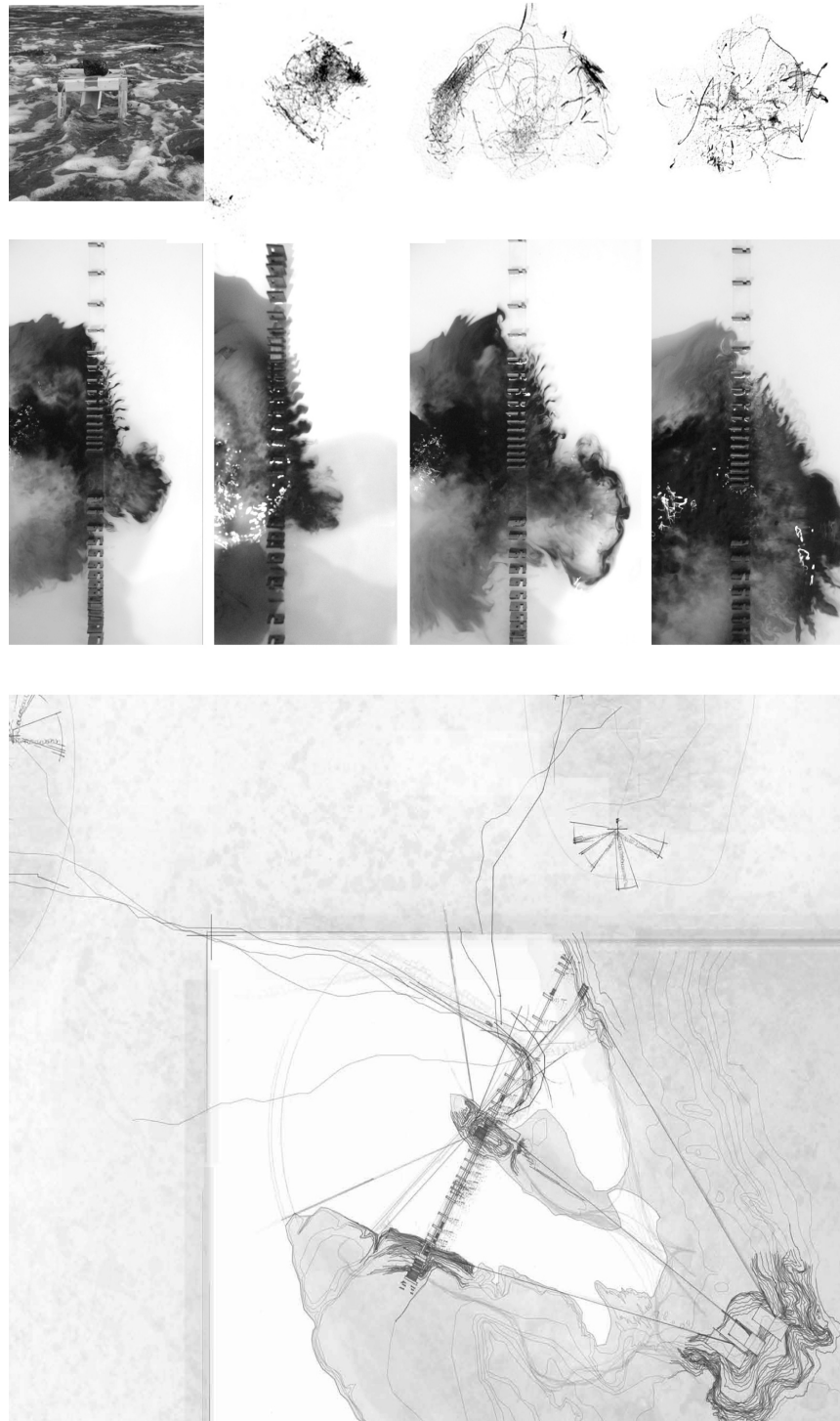
'time's arrow,' or directionality to processes, which work towards system equilibrium. Buildings are open systems in which the energetic inputs and outputs are in (often radical!) disequilibrium; as with all things in the natural world, buildings are in constant negotiation with their surrounding environment. This reciprocity highlights that buildings are part of a constant process of energy/matter negotiation in which energy, which is charged, fluctuating, dynamic and temporally thick, is understood in contrast to matter, which is, relatively speaking, static or inert. As Fernández-Galiano notes: "Architecture can be understood as a material organization that regulates and brings order to energy flows; and, simultaneously and inseparably, as an energetic organization that stabilizes and maintains material forms" (2000 p5).

### **DRAWING ENERGY: KERRERA**

In the Autumn of 2011<sup>2</sup>, I co-taught a University of Edinburgh third-year design studio that operated within this thermodynamically optimistic framework. In 'Drawing Energy: Kerrera', students designed active landscapes of cultivation and passive buildings that buffered the harsh Scottish coastal climate, where it rains 300 days a year and under-heating is the dominant concern year round. Energy was framed as work and as heat, the two basic outputs of any thermodynamic system. 'Heat' relates to building and landscape response to macro and microclimate, particularly the buffering, amplification or dampening of wind, rain and light. 'Work' is understood as effort required to cultivate local-scale industries ranging from aquaculture to slate quarrying to renewable energy production. Through drawing these acts of cultivation and climatic exchange, students made visible that which is generally spatially and experientially enigmatic.

One of the most pressing issues raised in the work produced involved clarifying the spatial and representational dialogue between energy and matter. Three of the energy/matter dialogues explored in the studio are elaborated here. Schematic and interrelated, they offer a starting point for conceiving of a more generous conception of architecture in thermodynamic terms.

Figure 1: Tom Ferm, Robert Hebblethwaite and Hayden White's project, 'Prawn Cultivation: Weathering and Character,' explored the invisible and behaviourally complex tidal conditions of their Kerrera coastal site. Drawing "machines" track tidal conditions on site, offering turbulence as a particularly important condition for further exploration (Top). A series of ink-dyed fluid models tested turbulence and tidal flow patterns around a designed wave break. The wave break fins were adjusted and configurations calibrated in order to create zones of limited turbulence, easing boat navigation and docking along the rocky Kerrera shoreline (Bottom).



### DIALOGUE 1: FLUID FRONTS (Figure 1)

Energetic exchanges often occur in fluids, both air and water. Thermal boundaries, for example, are present at the intersection of any two thermal systems with a heat differential. When that differential is great enough, it is perceived, giving it spatial relevance. Addington notes:

“Thermodynamic boundaries are not legible and tangible things, but instead are zones of activity, mostly non-visible. In this zone of activity—the boundary—the truly interesting phenomena take place. This is where



energy transfers and exchanges form, and where work acts upon the environment... boundary operates as fundamental transition zone for mediating the exchanges between two or more static variables"s (2005, p51).

Similar fronts occur when air or water flow is obstructed or directed through and around fixed material conditions; laminar flow becomes turbulent, resulting in perceivable eddies and vortices.

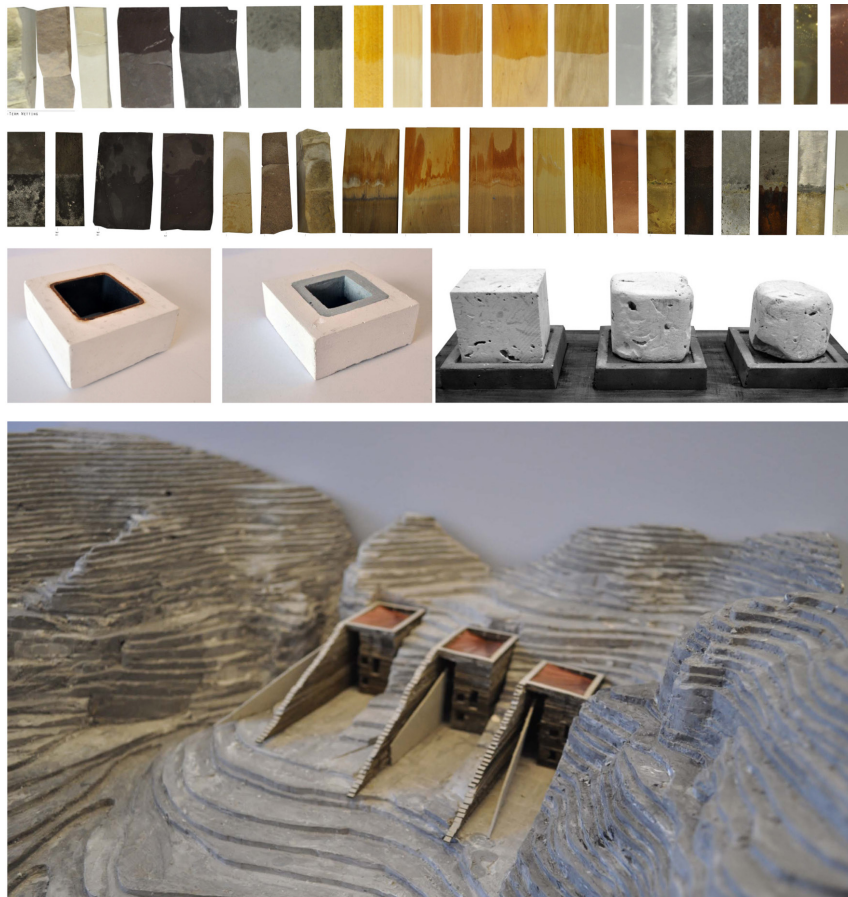
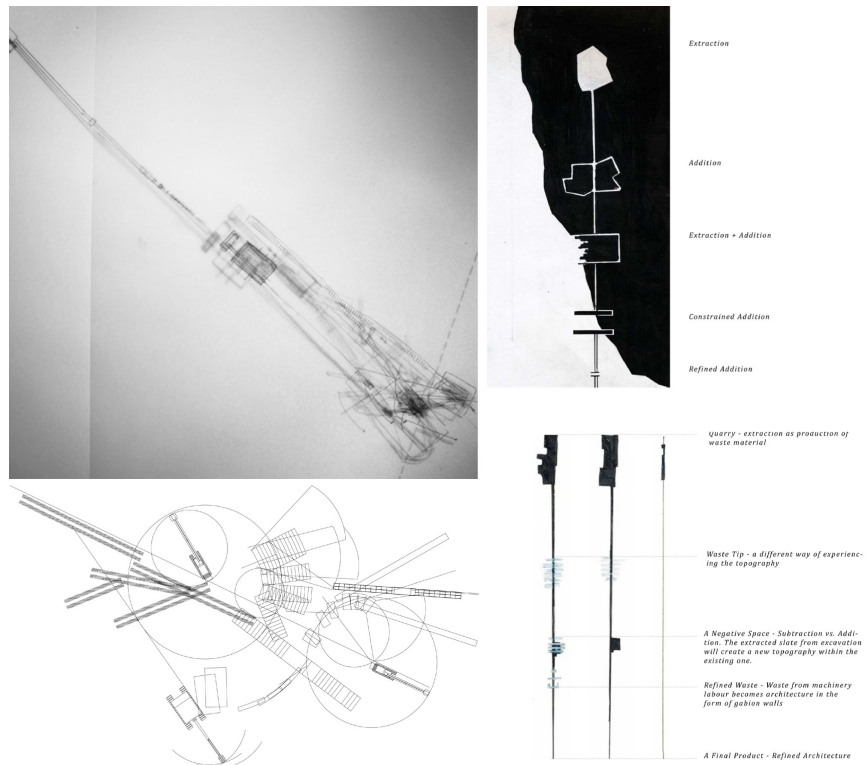


Figure 2: Sited at the apex of the cove, Tom Ferm's fisherman's dwelling allows for panoramic observation of multivalent weathering shifts on site. These shifts operate at a vast range of timescales, from the geological time-scale of the erosion of dolerite bands within the adjacent limestone vein, to the annual patina of copper roof that gathers and channels rainwater, to the daily tidal patterns and turbulence buffered by the wave break. Extended retaining wall "tails," one solid stone and one timber, buffer from prevailing wind and erode/weather at varying rates depending on orientation and interior/exterior disposition. Short and long-term weathering studies of concrete, slate, wood and metal (top) and exploration of material wear due to long term erosion (middle) inform an architectural strategy for the dwelling. The dwelling is in material dialogue with the geological shelf on the site (bottom) and in visual dialogue with the turbulent coastline and meteorological conditions above, around and beyond.

## DIALOGUE 2: MATERIAL REGISTRATION (Figure 2)

Dialogue 1 decoupled material and energy; dialogue 2 recouples them. Solid materials visibly, tactilely and acoustically register energetic exchanges; they are energy conduits. Materials absorb, reflect, emit, and transmit radiation to varying degrees; these properties are visually or thermally registered on a material's surface. Radiant energy/material exchanges highlight a temporal disconnect between the relatively static world of construction material and the active world of energetic exchange. While construction materials weather, patina or erode over time, relatively speaking, they are static and longevity is measured in years or decades rather than seconds. It is because of this temporal disjunction that materials can provide a static, relatively speaking, backdrop to the energetic exchanges that occur upon them.

Figure 3: Maria Esteban Casanas and Susanna Boreham designed a slate quarry and associated buildings for stone fabrication. Their project, 'From the Unrefined to the Refined,' opportunistically closes the material loop of production. The site actively records the process of material extraction and topographic alteration. Diagrams indicate active processes of slate extraction, processing and site occupation contained within the site (top). These processes are registered as a "blurry" experiential landscape that records the labour required to cultivate the site (bottom).



### DIALOGUE 3: MATERIAL GEOGRAPHIES (Figures 3 and 4)

The harvesting, mining, and processing of raw materials and their transport typically reflects a vast global network of energetic exchanges. These exchanges are often quantified as part of embodied energy calculations, yet the physical inscriptions and the entropic landscapes marked by these processes are often neglected. As Moe notes:

*"Architects are disproportionately aware of the constructions they propose and woefully unaware of the inverse architecture of material extraction, production, and transportation...The production and application of materials alter unseen ecologies, sway local and distant economies, amplify or inhibit social progress, and even engender the rise and fall of cultures. Only architects with an operational sense of the history, processes, and distribution of materials will sufficiently comprehend and thus alter material usage toward sustainable ends."* (2007).

Work produced in the studio has raised a number of questions that require further investigation: given that energetic exchanges occur at radically diverging scales-- from the microscopic to the meteorological-- to that of conventional building materials, what scales of observation, both spatial and temporal, are most conducive to designing thermodynamically? Should these scales be tied to the behaviour of the thermal conditions being explored, to the physiology of the human body, or to the limits of the instruments of their measure? Is there a way of expanding architecture's energetic vocabulary to incorporate taxonomies that have richer spatial and experiential implications than the conventional embodied/operational, renewable/non-renewable models? What drawing and modelling tools and

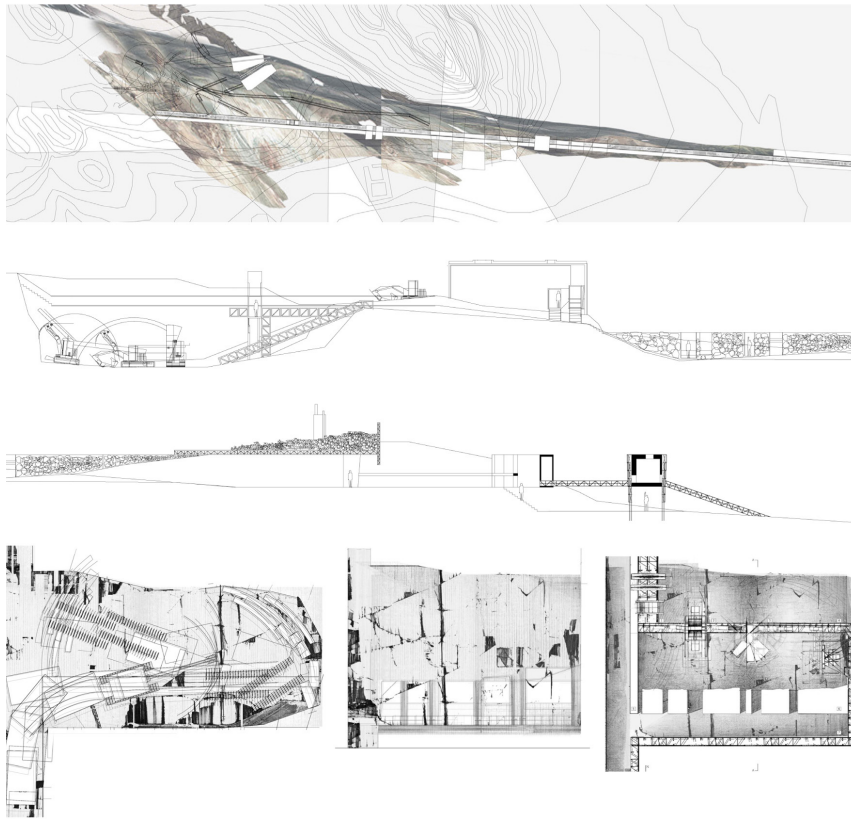


Figure 4: The negative landscape of the quarry is counter-posed with additive experiential landscape, an inhabitable waste tip that, over time, alters the inhabitants' line of horizon. All processes associated with the extraction and production of slate are organized along a central "axis of refinement," ranging from rough subterranean "quarried" buildings to floating buildings constructed of honed slate cladding (top). Reciprocity between the quarried void and the material removed is further developed at the building scale. Buildings become increasingly refined, which is registered materially through subtractive or additive construction (bottom).

techniques best test and represent these shifting, fluctuating, charged, invisible conditions?<sup>3</sup>

Architecture is caught in a curious methodological bind: while we have a range of tools and techniques to test ideas, rarely is there a single prescribed question or problem given at the outset of the design process. Through the discursive and the intuitive, ideas are tested, the framing of a problem refined. The basic framing of energy as work and as heat, the drawing of these conditions on site, and the critical reflection of the issues raised by work produced in the studio goes a small way towards developing a thermodynamic conception of architecture, but it starts to liberate a topic that has tangible spatial consequences and has been marginalised in sustainable discourse.

## NOTES

1. This interest in developing ways of conceiving of energy spatially builds on Banham's "structural" versus "power-operated" architectural environmental response distinctions explored in *The Architecture of the Well-Tempered Environment* (1984). Approaches for conceiving of architecture thermodynamically vary from a bioclimatic technical perspective by Hassan Fathy, to metaphorical comparisons between thermodynamic conditions and spatial configurations by Luis Fernández-Galiano. Philippe Rahm leverages a sound technical understanding of thermodynamic principles towards designs that heighten experiential



awareness of “thermally asymmetric” conditions (2009 p33). In, ‘The New Somatic Architecture,’ Christopher Hight explores the spatial and representational consequences of “environmentally affective” conditions (2009). Work by Addington, Moe, Gissen, Lally and others also challenge the static understanding of energy as quanta that powers buildings.

2. In Autumn 2011, Drawing Energy Kerrera was co-taught with Victoria Bernie.

3. Elaborations of these key questions and reflections of student work from the Drawing Energy Abu Dhabi studio, taught in 2010, are explored in more detail in “Drawing Energy Abu Dhabi: Critical Reflections,” published as part of conference proceedings for the 2011 ACSA 100th Annual Meeting within the “Emerging Materials, Renewable Energy, and Ecological Design” panel.

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